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Title: Using LGI experiments to achieve better understanding of pedestal-edge coupling in NSTX-U

Author(s): Wang, Zhehui

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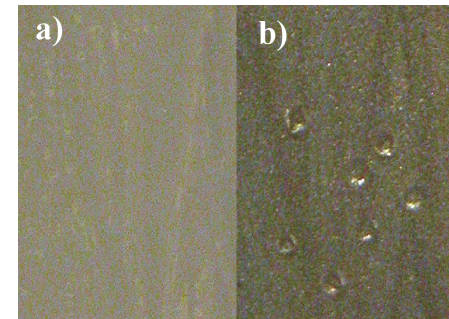
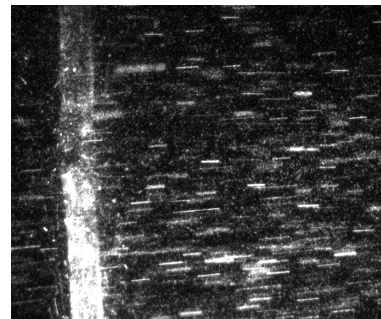
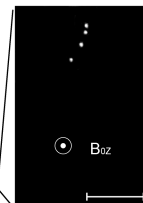
Using LGI experiments

To achieve better understanding of pedestal-edge coupling in NSTX-U

Zhehui (Jeff) Wang

Los Alamos National Laboratory

NSTX collaboration meeting, PPPL
(Feb. 22-27, 2015)



Abstract

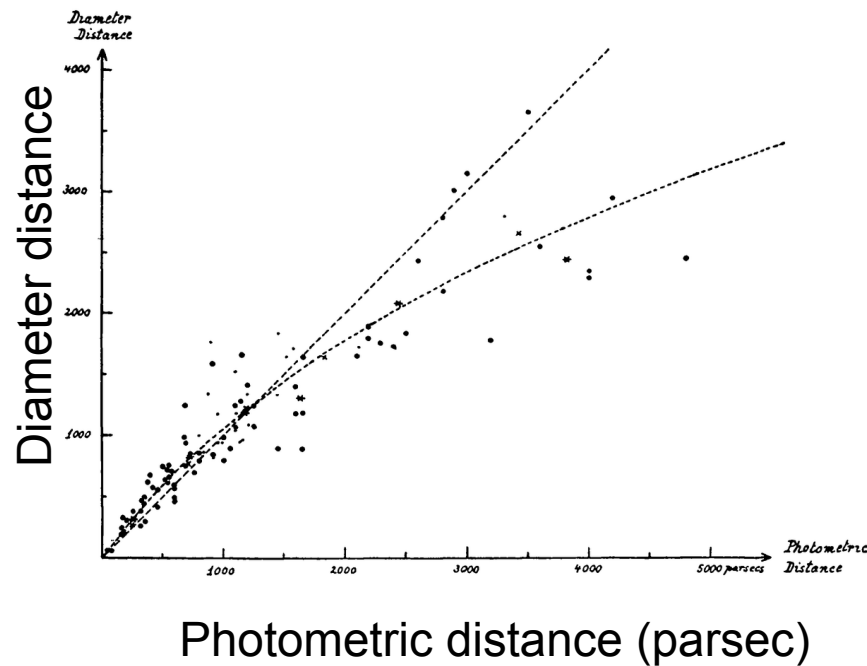
Latest advances in granule or dust injection technologies, fast and high-resolution imaging, together with micro-/nano-structured material fabrication, provide new opportunities to examine plasma-material interaction (PMI) in magnetic fusion environment. Some of our previous work in these areas is summarized. The upcoming LGI experiments in NSTX-U will shed new light on granular matter transport in the pedestal-edge region. In addition to particle control, these results can also be used for code validation and achieving better understanding of pedestal-edge coupling in fusion plasmas in both NSTX-U and others.

Outline

- **Intro & previous work**
 - Dust transport studies
 - hypervelocity dust injection for fusion energy
 - In-situ dust cloud imaging (micron & larger grains)
- **Opportunities with LGI experiments**
 - Imaging + Injector + Materials (dust/granules, wall)
 - The gap between observations & understanding
 - Better (high spatial resolution, non-invasive) characterization of edge/pedestal plasmas

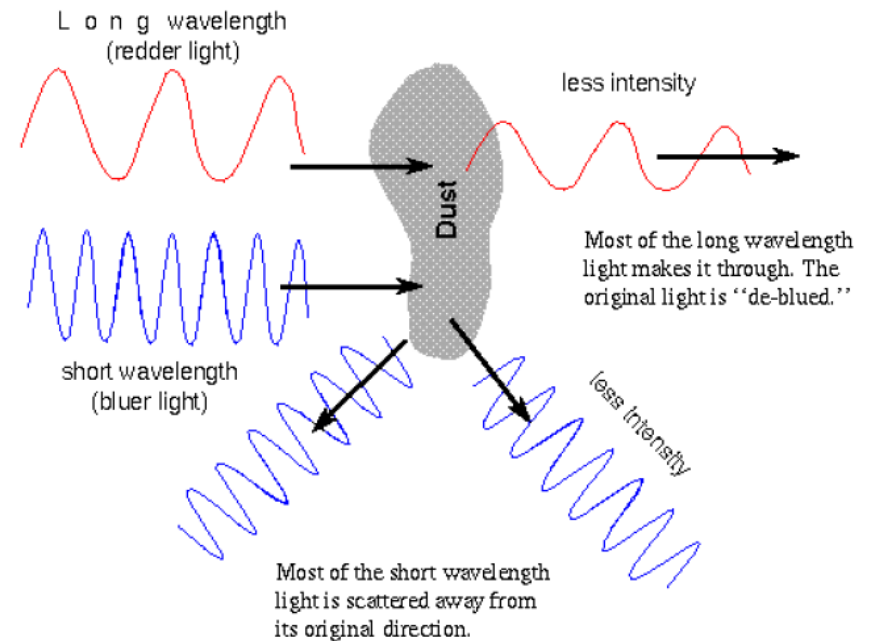
Dust as 'surprises' in many fields → Interstellar dust

Robert J. Trumpler (1930)



1 parsec = 2.06×10^5 AU = 3.26 ly

Reddening and Extinction



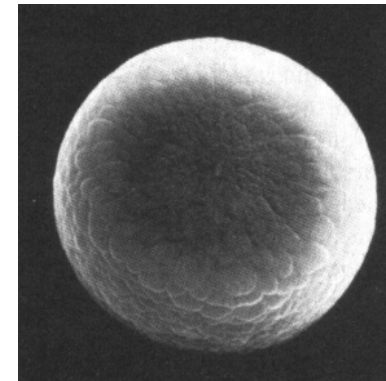
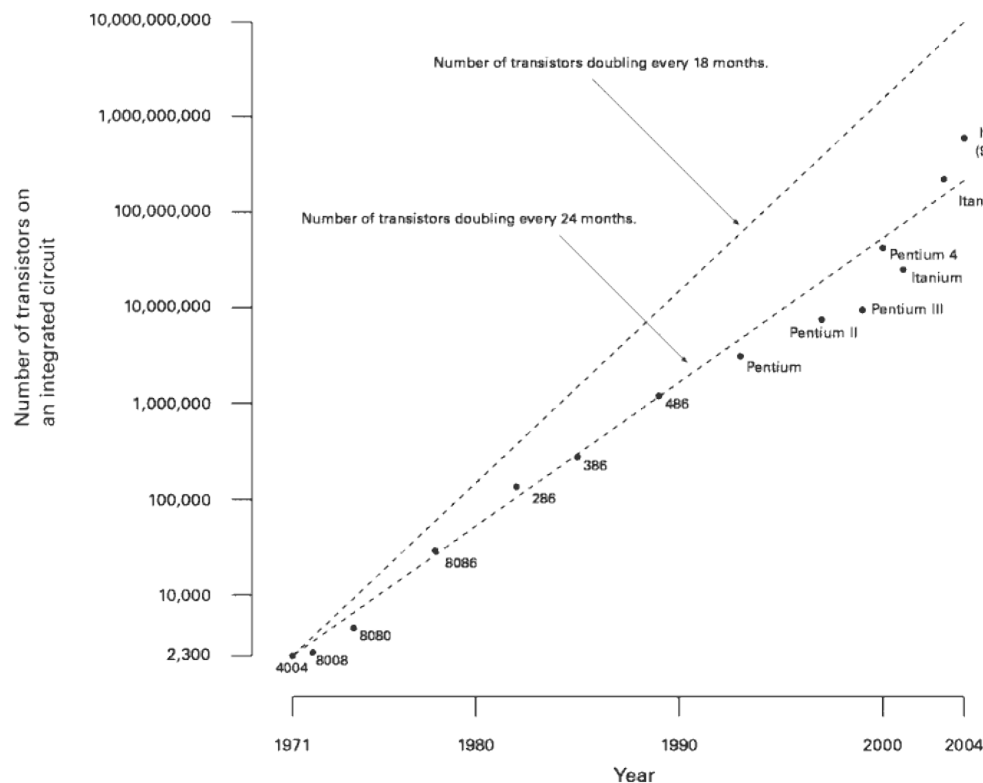
Rayleigh scattering

$$I_{\text{scat.}} \propto \lambda^{-4}$$

Semiconductor fabrication

Moore's Law

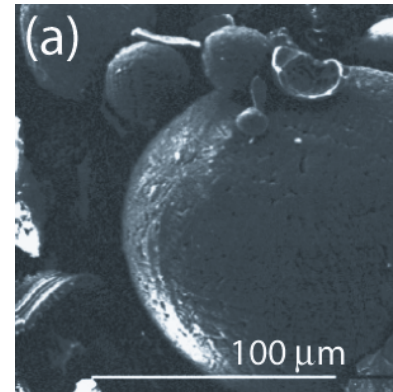
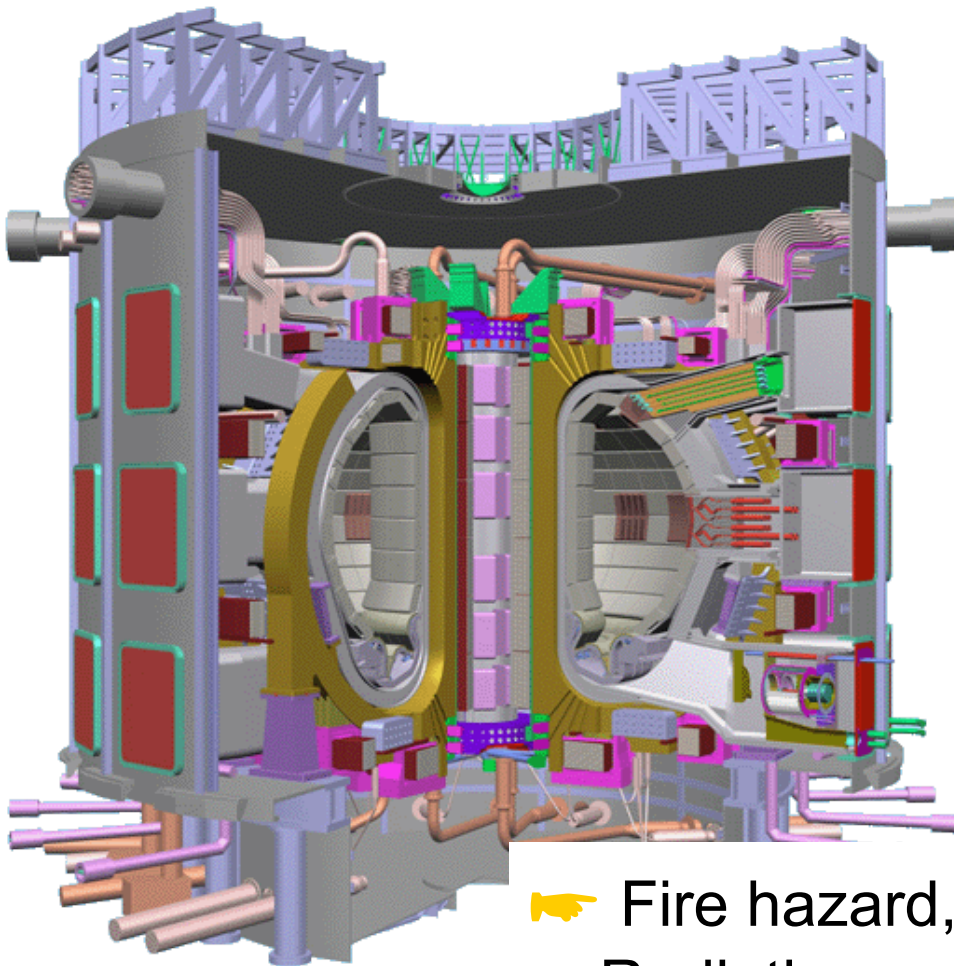
G. S. Selwyn, *et al.* JVST (1989)



In-situ production of dust by processing plasma observed and analyzed.

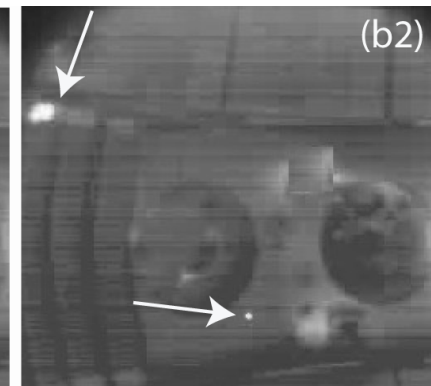
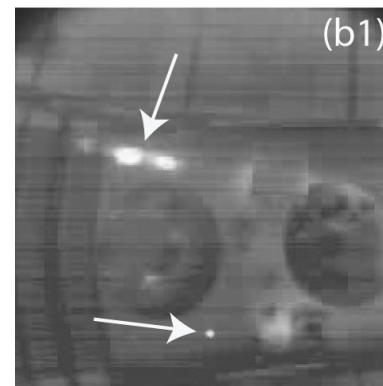
👉 clean room is not a solution

Dust in magnetic fusion: “seems all bad”



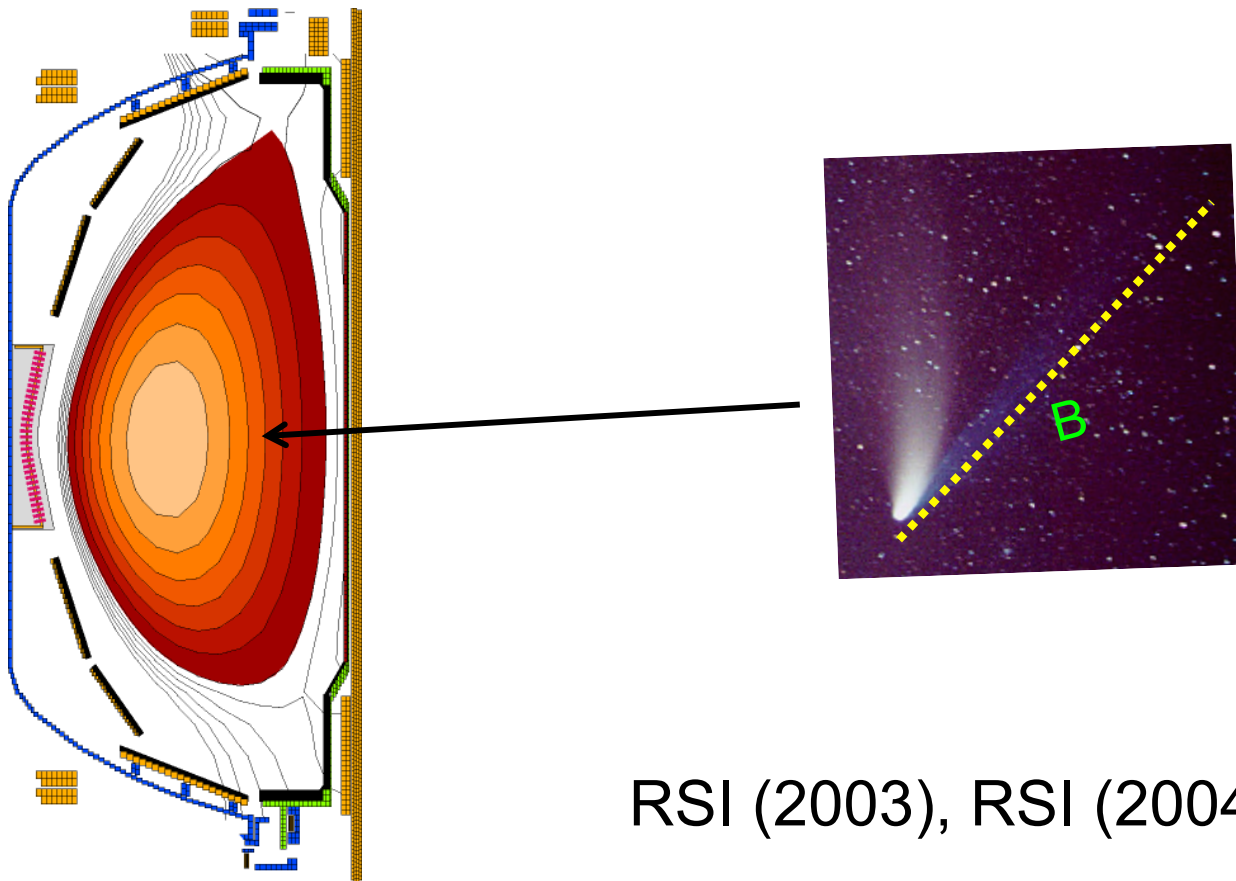
Winter, PoP (2000)

Roquemore et al. (2006)



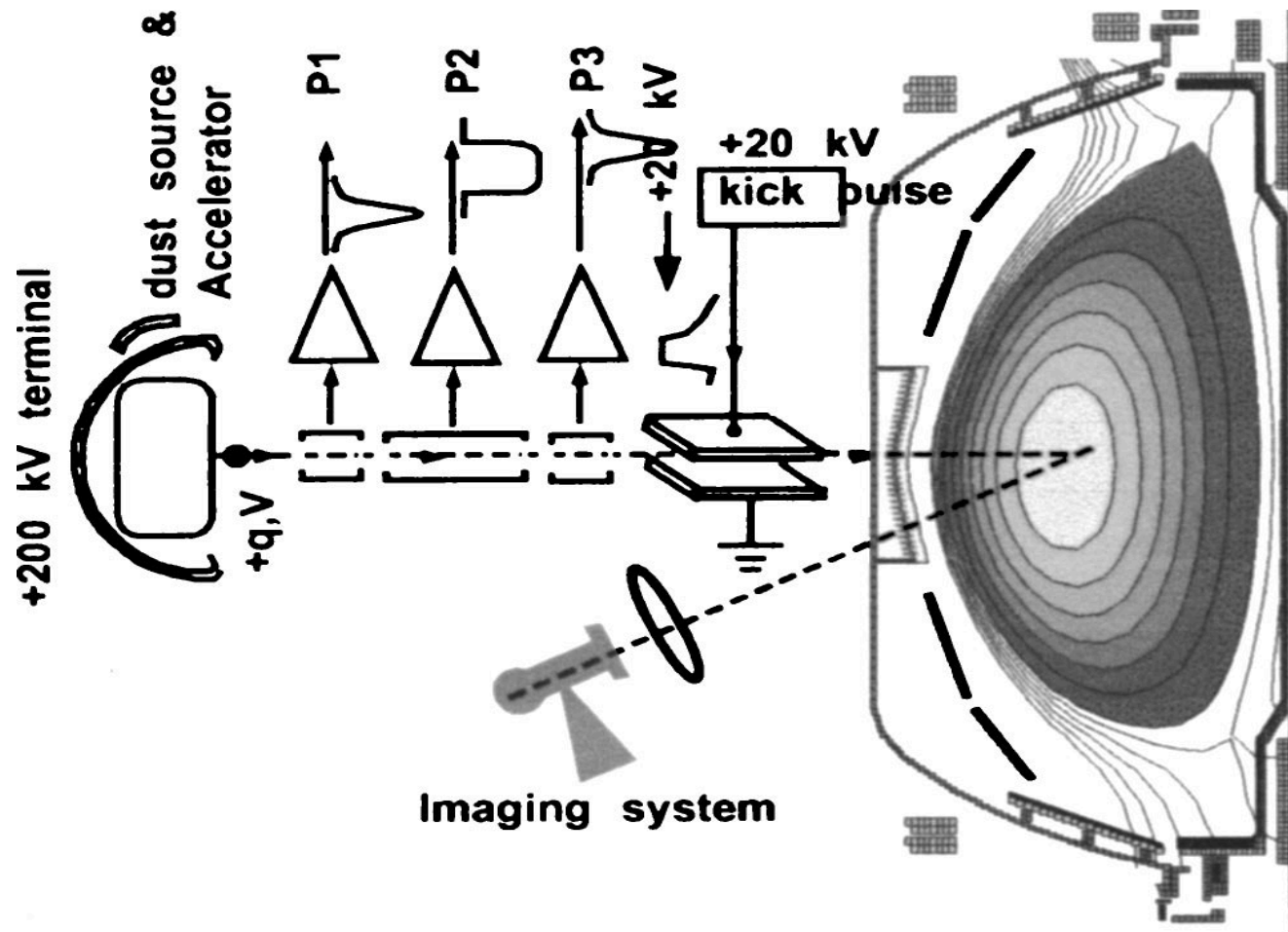
- 👉 Fire hazard, radioactive material transport
- 👉 Radiative cooling of fusion reactor

Hypervelocity dust injection

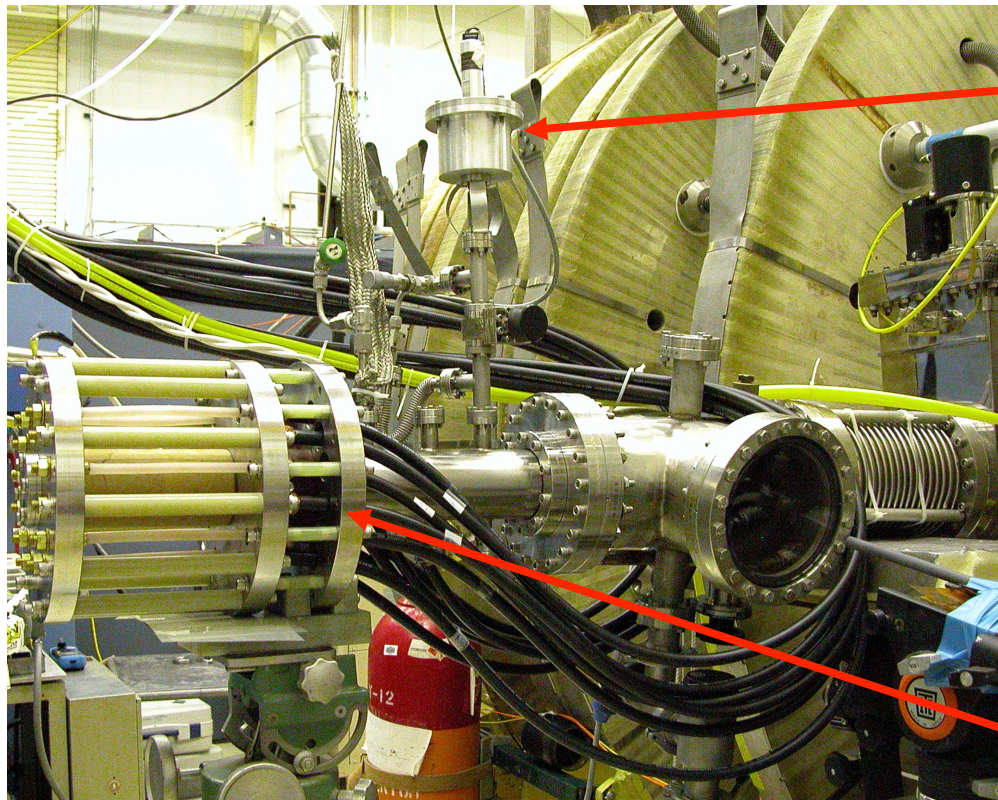


RSI (2003), RSI (2004)

The electrostatic approach

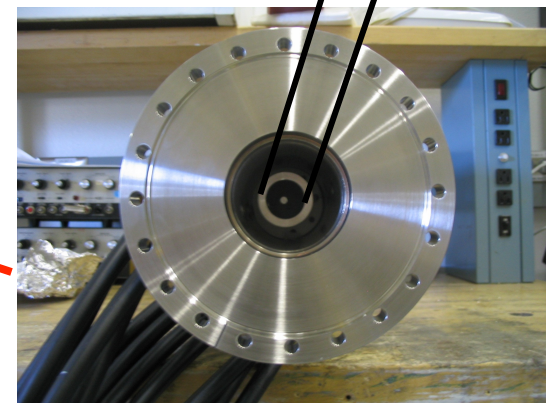


The coaxial plasma accelerator

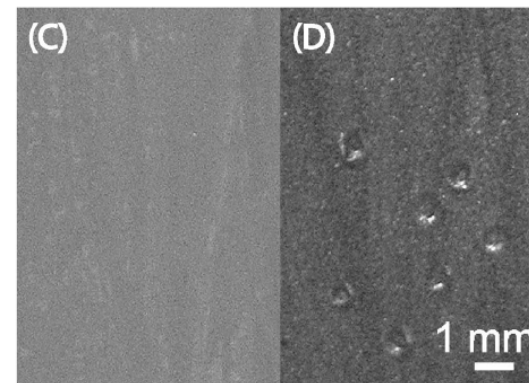
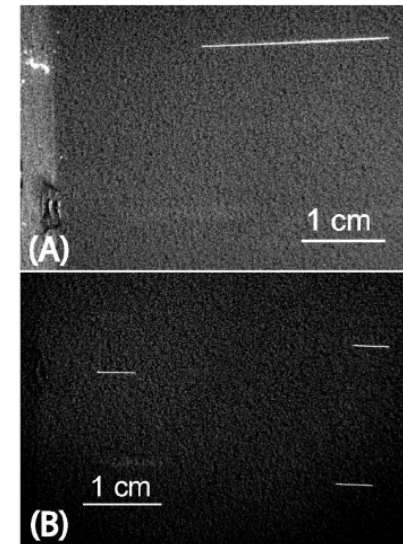
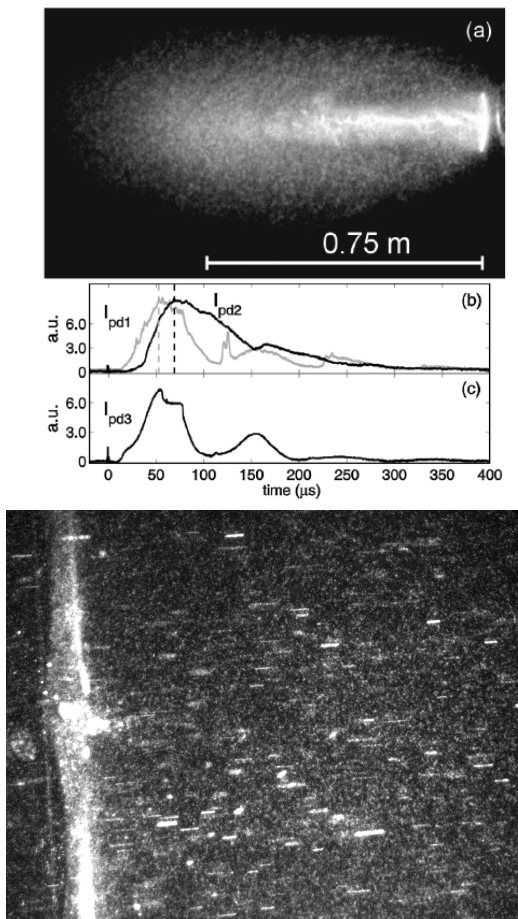


Dust reservoir

ϕ 4.4 cm

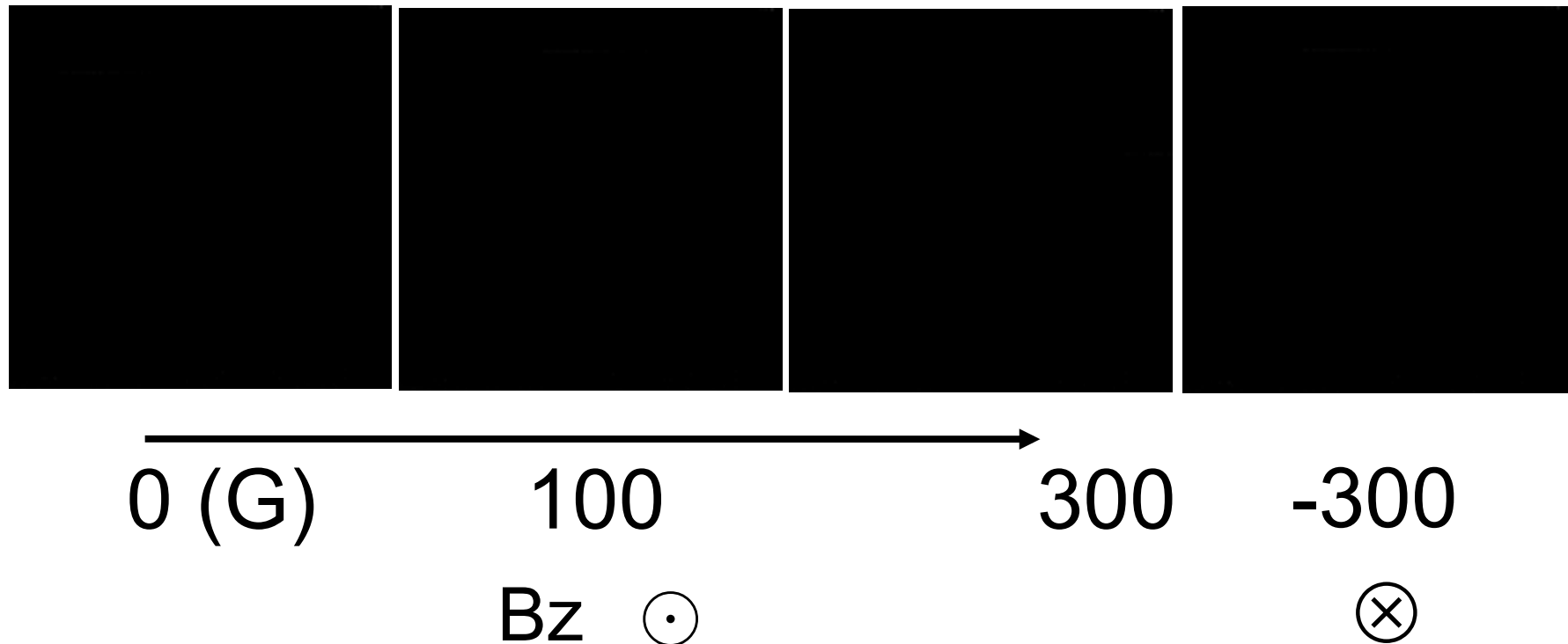


Hypervelocity dust injection and in-situ measurement



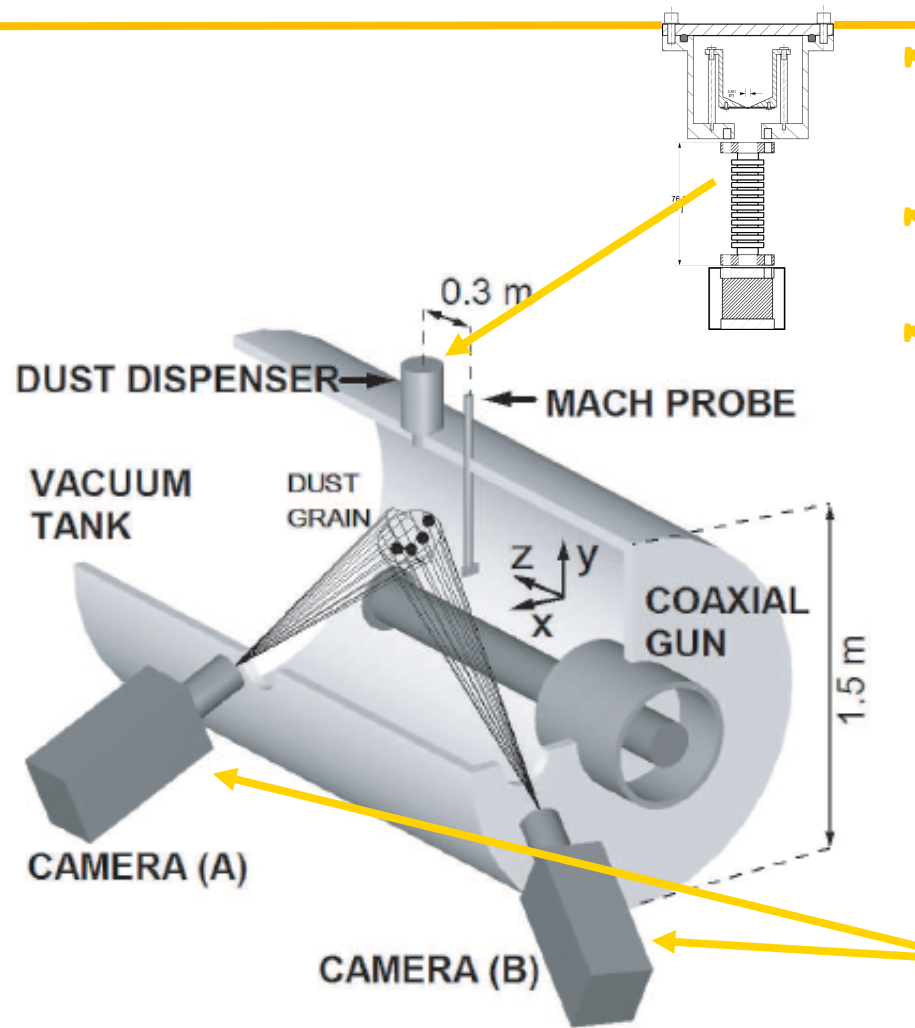
Z. Wang *et al*, PoP **14** (2007) 103701

Studying of plasma flows



👉 rotation direction is determined by $\mathbf{J} \times \mathbf{B}$ torque

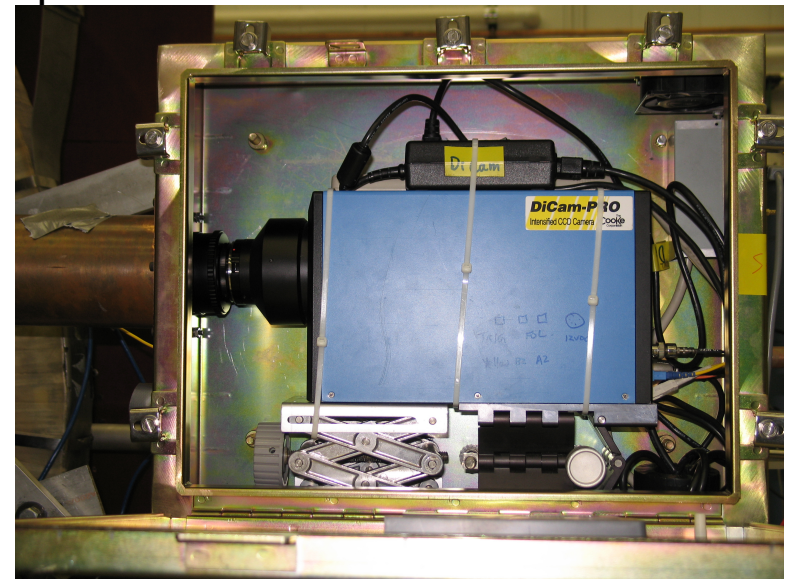
Using dust for flow measurements



➡ The falling time (0.1-0.2 s) >>

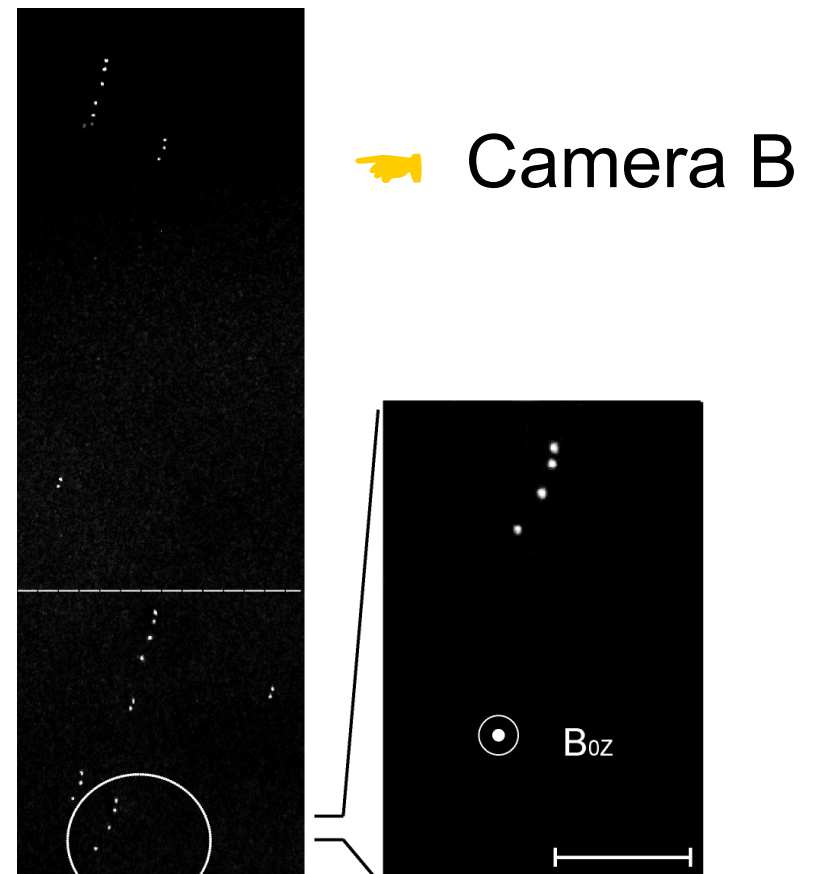
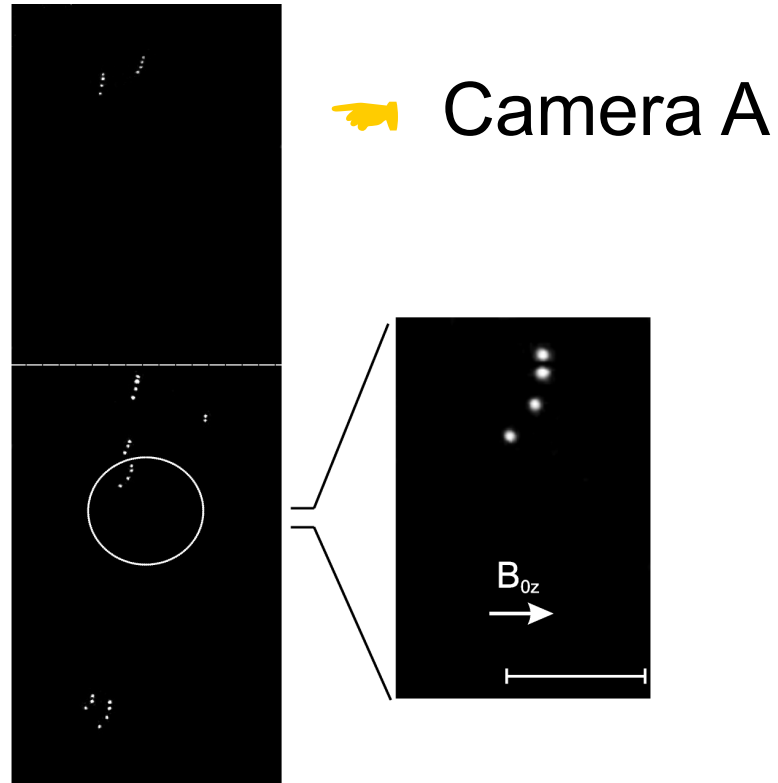
$\tau_{pl.}$ (~ 10 ms)

➡ Dust were pre-dropped before the plasma shot/discharge,
 ➡ The dust grains are ~ *at rest* relative to the rapid moving plasma.

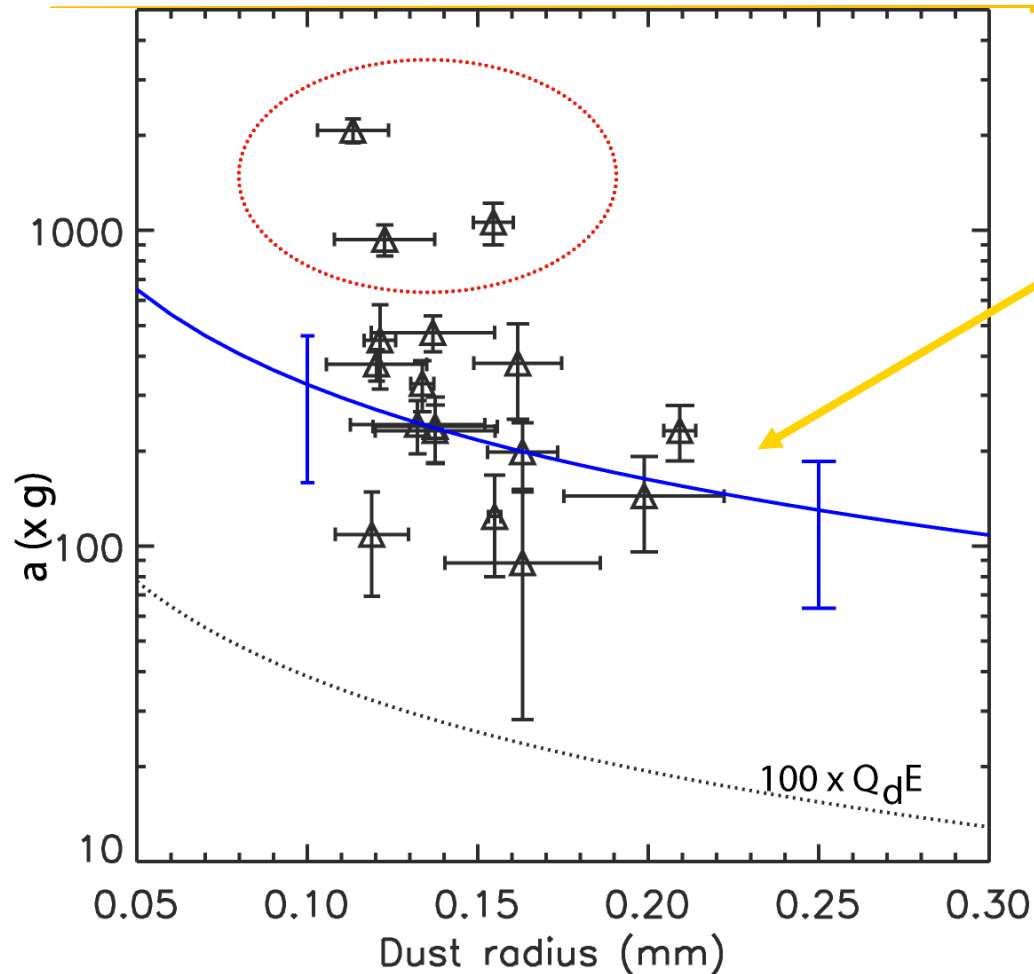


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Dust trajectories recorded



Dust motion is dominated by 'impact' drag



$$\mathbf{F}_{pf} = 2\pi r_d^2 k_B T_i n_i \xi \mathbf{w}$$

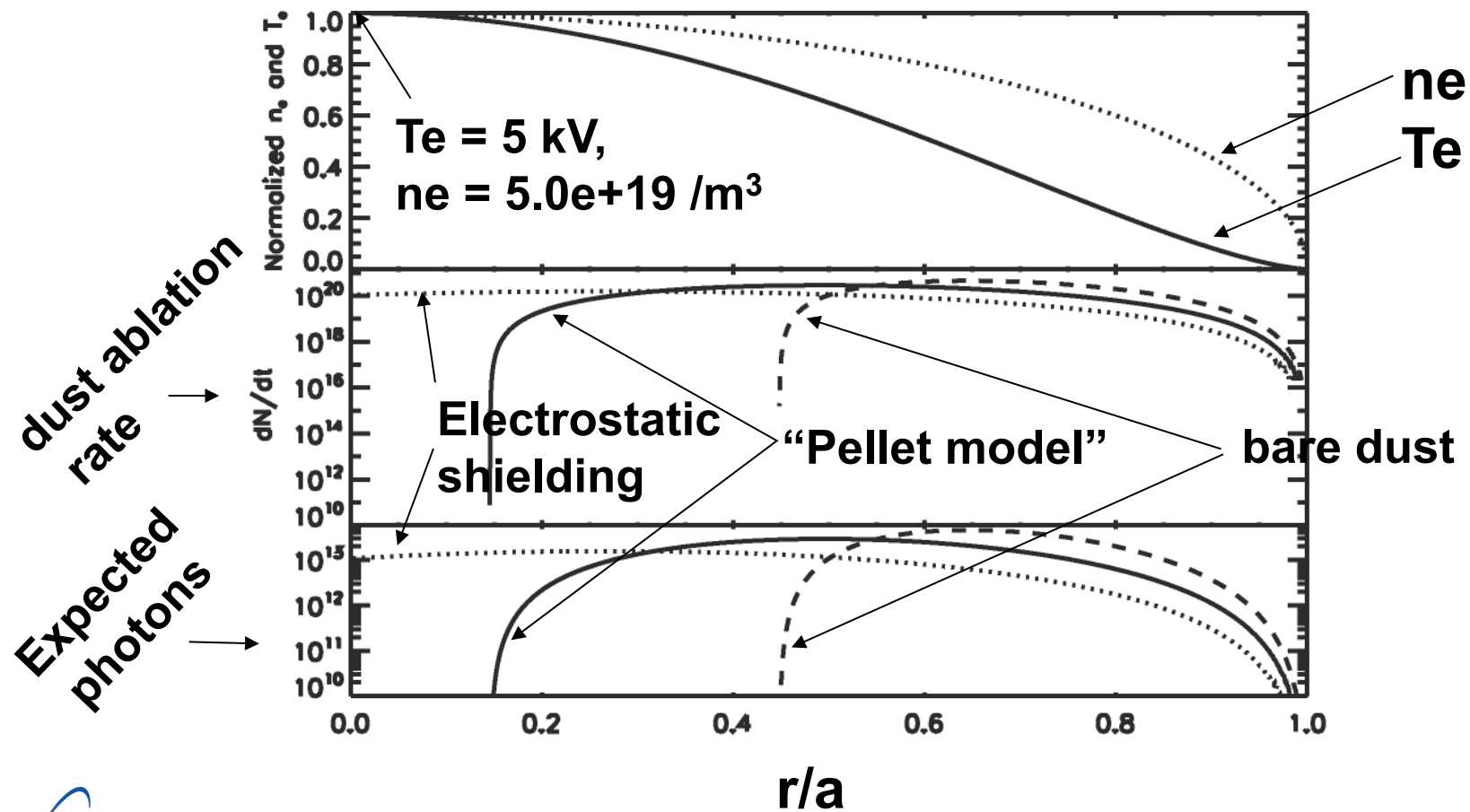
other forces are small

Dust can become a new
technique for plasma
flow

R&D opportunities

- **Granule/dust –plasma interactions**
 - Fundamental physics of granule/dust – high-temperature plasma interactions
 - Safety, hazards (code validation)
 - Edge/pedestal plasmas (ELMs pacing, disruption mitigation)
- **Pedestal-edge coupling**
 - High spatial-temporal measurement
 - First wall (material) development
- **Injector technology + micro/nano-fabrication**
 - Tailored material properties
 - Tailored injection conditions
- **Imaging technology**
 - Real time particle tracking
 - High spatial and temporal resolutions

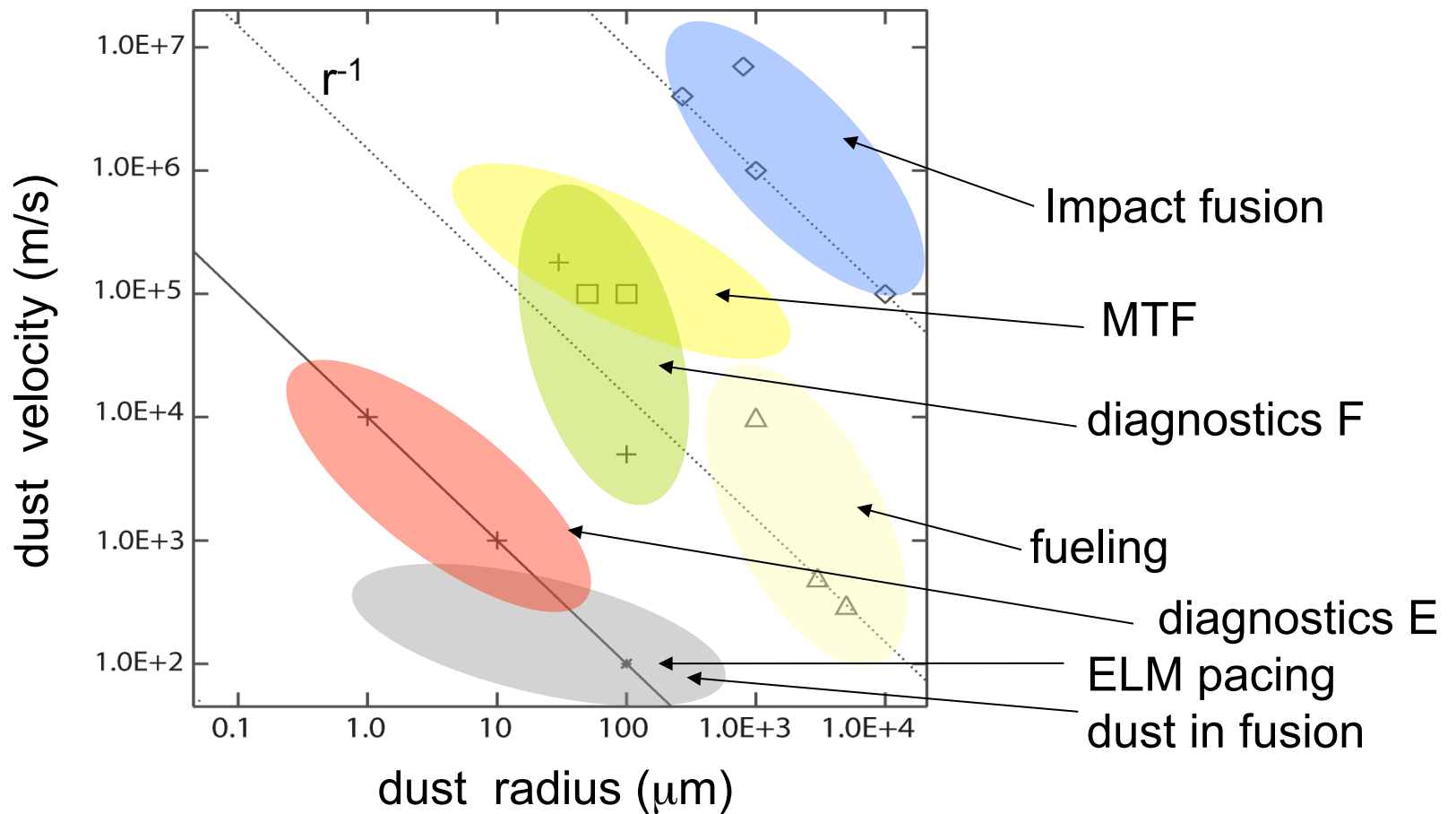
Transport varies significantly with models



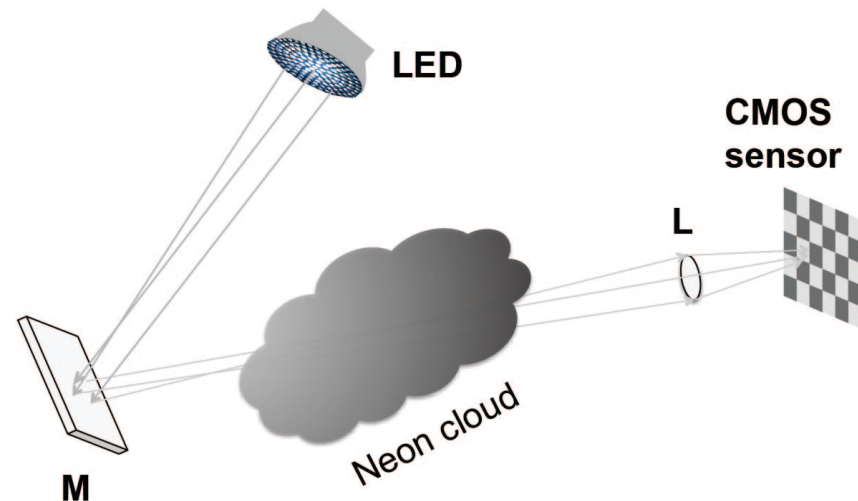
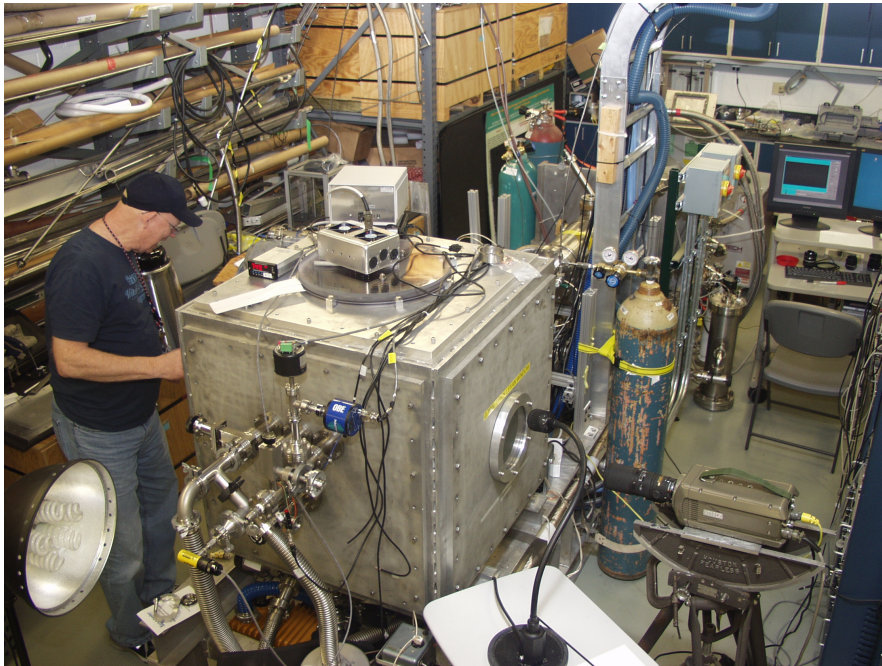
Carbon dust, 25 μm , 10 km/s

Injector technology roadmap

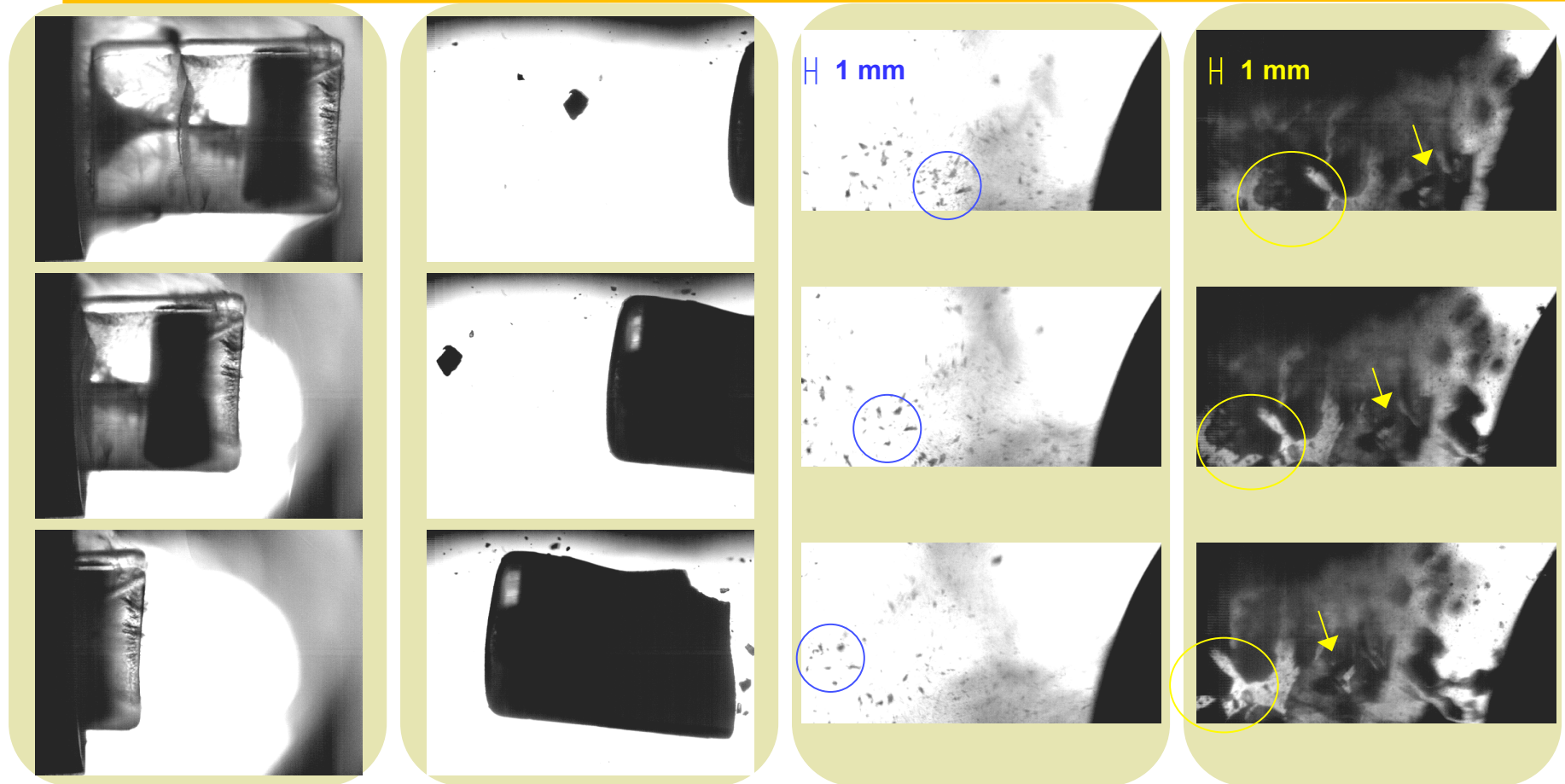
Z. Wang *et al*, AIP Conf. Proc. **1041** (2008) 135




High-speed tracking of granular matter (1)



High-speed tracking of granular matter (2)



 **V=310 m/s**
Los Alamos
 NATIONAL LABORATORY
 EST. 1943

V=220 m/s

V=276 ± 30 m/s

V=223 ± 8 m/s

UNCLASSIFIED

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Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

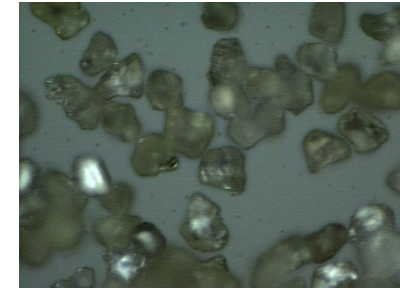
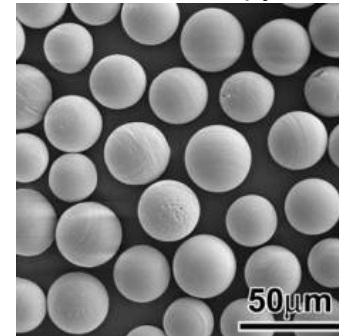
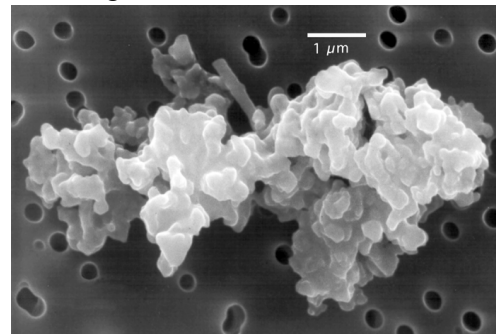


Tailored material properties

Porous chondrite interplanetary dust particle.
Courtesy of E.K. Jessberger, Institut für Planetologie, Münster, Germany, and Don Brownlee, University of Washington, Seattle.

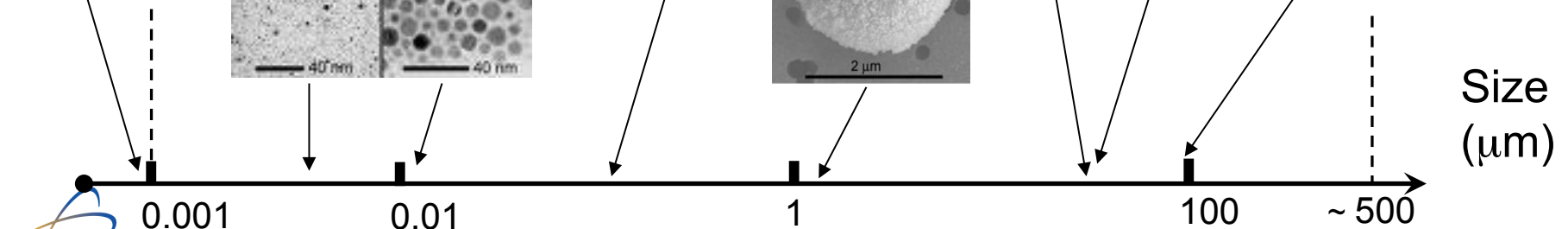
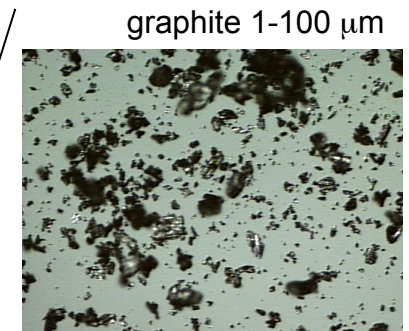
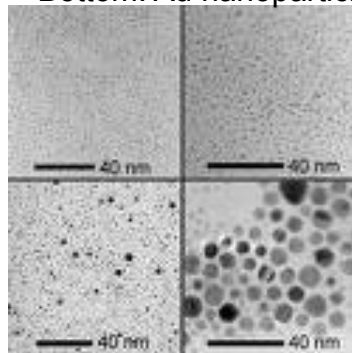
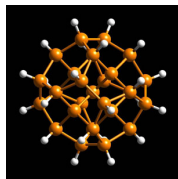
SEM image of Y₂O₃ microspheres for radiotherapy

diamond
mean size 50 μm



A computer-generated nanoparticle of 1 nm diameter (Si₂₉H₂₄).

Top left: platinum. Si (orange); H (white). Top right: palladium. Bottom: Au nanoparticles.



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